

Resonances from Baryon decuplet-Meson octet interaction

M. J. Vicente Vacas, E. Oset and Sourav Sarkar

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Departamento de Física Teórica and IFIC, Centro Mixto Universidad de Valencia-CSIC, Institutos de Investigación de Paterna, Aptd. 22085, 46071 Valencia, Spain

Abstract

The s-wave interactions of the baryon decuplet with the octet of pseudoscalar mesons is studied in a unitarized coupled channel approach. We obtain a fair agreement for mass and width of several $\frac{3}{2}^-$ resonances. In particular, the $\Xi(1820)$, the $\Lambda(1520)$ and the $\Sigma(1670)$ states are well reproduced. Other resonances are predicted and also the couplings of the observed resonances to the various channels are evaluated.

1 Introduction

The use of unitary coupled channel methods in a chiral dynamical treatment of the meson baryon interaction has led to a good reproduction of low energy meson baryon data and to the dynamical generation of many low lying resonances which can be best described as quasibound meson baryon states [1, 2, 3, 4, 5, 6, 7].

Detailed studies of the $SU(3)$ breaking of the problem have shown that there are actually two octets and one singlet of dynamically generated baryons with $J^P = 1/2^-$, coming from the s-wave interaction of the octet of pseudoscalar mesons of the pion and the octet of stable baryons of the proton [8, 9].

The success of this approach motivated further searches and recently it was found that the interaction of the baryon decuplet of the Δ and the octet of mesons of the pion gives rise to a set of dynamically generated resonances [10]. In Refs. [11, 12] we conducted a systematic search of these $J^P = 3/2^-$ resonances by looking at their poles positions in the complex plane. We also calculated the residues at the poles, which allowed us to determine partial decay widths. In addition, we did a systematic study of the evolution of the poles as $SU(3)$ symmetry is gradually broken. In this talk, we will present some selected results of these works.

2 Meson Baryon scattering amplitude

Starting from the lowest order chiral Lagrangian for the interaction of the baryon decuplet with the octet of pseudoscalar mesons[13] we obtain the s -wave transition amplitudes

$$V_{ij} = -\frac{1}{4f^2}C_{ij}(k^0 + k'^0). \quad (1)$$

The coefficients C_{ij} are given in Ref. [12]. This amplitude is used as the kernel of the Bethe Salpeter equation to obtain the transition matrix fulfilling exact unitarity in coupled channels.

We begin our search for poles in the $SU(3)$ limit which is obtained by putting an average mass for the decuplet baryons and for the octet mesons. We then study the trajectories of these poles in the complex plane as a function of a parameter x which controls the breaking the $SU(3)$ symmetry gradually up to the physical masses of the mesons and baryons. In the $SU(3)$ limit we find two poles on the real axis. One of them is found to correspond to a bound state belonging to the octet and the other one to the decuplet representation. As the symmetry is broken gradually, different branches for each combination of S, I appear. This means four branches each for the octet and the decuplet. We plot the resulting trajectories for the octet and decuplet representations in Fig. 1. For the octet (left panel), all the trajectories coincide in the $SU(3)$ limit at 1673 MeV. Of the four branches, all except the one with $S = -2, I = \frac{1}{2}$ move to lower energies. The one corresponding to $S = 0, I = \frac{1}{2}$ disappears at $x = 1$ where it reaches the $\Delta\pi$ threshold. In the case of the decuplet representation, all the branches coincide at 1738 MeV in the $SU(3)$ limit. Two of the branches move to lower energies and two shift towards higher energies with increasing value of x . The pole with $S = -2, I = \frac{1}{2}$ disappears at the $\Sigma^*\bar{K}$ threshold in the limit of the physical masses. The poles which disappear are marked with a ?-sign in fig. 1. Similar results are obtained independently of the initial baryon and mesons masses. See Ref. [12] for a discussion of poles corresponding to the 27 and 35 representations.

We now can determine the couplings of the resonances with the different physical states which are the residues at the poles of the scattering matrix. As an example we show the results for $S = -1$ and $I = 1$. For these quantum numbers we find three poles of the scattering amplitude for the channels $\Delta\bar{K}$, $\Sigma^*\pi$, $\Sigma^*\eta$ and Ξ^*K in the second Riemann sheet of the complex energy plane at $(1632 \pm i15)$, $(1687 \pm i178)$ and $(2021 \pm i45)$ MeV.

The first pole appears in the evolution of the octet poles and the second one of the decuplet. The third pole is tied to the 27-plet. The couplings of the resonances to the different states are shown in table 1. The pole at 1632 MeV is visible as a narrow peak on the real axis with a very strong coupling to $\Delta\bar{K}$. This peak can be associated to the 4-star resonance $\Sigma(1670)$. The width of about 30 MeV corresponds to the $\Sigma^*\pi$ decay since the other channels are closed. No numbers are yet provided for this decay in the PDB. Further experimental research into the meson-meson-baryon decay channels would be welcome.

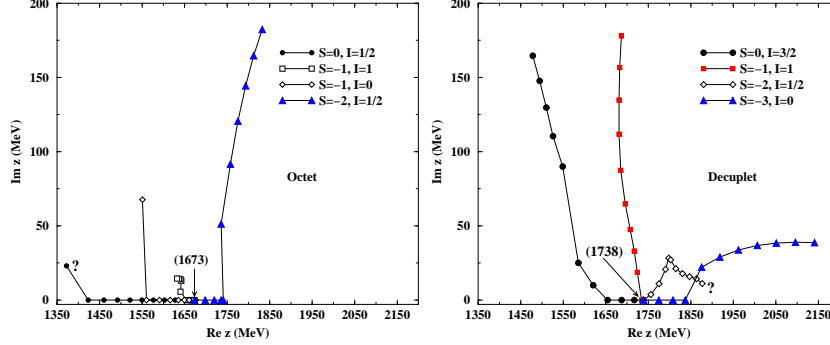


Figure 1: Trajectories of the poles in the scattering amplitudes obtained by increasing the $SU(3)$ breaking parameter x from zero to for the octet (left) and decuplet (right) representations. The poles which disappear are indicated by a ?-sign.

We find a second pole at 1687 MeV with a much larger width which does not allow it to show up in the scattering amplitude over the real axis. The third pole couples strongly to the $\Xi^* K$ and produces a small bump on the real axis. It could correspond to the $\Sigma(1940)$ as also claimed in Ref. [10].

Table 1: Couplings of the resonances with $S = -1$ and $I = 1$.

z_R	1632 + $i15$		1687 + $i178$		2021 + $i45$	
	g_i	$ g_i $	g_i	$ g_i $	g_i	$ g_i $
ΔK	$3.7 + i0.03$	3.7	$0.4 + i1.7$	1.8	$0.4 + i0.5$	0.6
$\Sigma^* \pi$	$1.1 - i0.4$	1.1	$2.2 + i2.0$	3.0	$0.3 - i0.8$	0.8
$\Sigma^* \eta$	$1.8 + i0.3$	1.9	$1.9 - i0.6$	1.9	$1.0 + i0.7$	1.2
$\Xi^* K$	$0.3 - i0.5$	0.6	$2.7 + i1.4$	3.0	$2.5 - i1.0$	2.7

Results of similar quality are obtained for the rest of S, I channels and can be found in Ref. [12]

3 Conclusions

The s-wave interaction of the baryon decuplet with the meson octet generates dynamically several $3/2^-$ resonances. We have searched their pole positions in the complex plane in different Riemann sheets. The search was done starting from an $SU(3)$ symmetric situation. We found attraction in an octet, a decuplet and the 27 representation, while the interaction was repulsive in the 35 representation. In the $SU(3)$ symmetric case all states of the $SU(3)$ multiplet are degenerate and the resonances appear as bound states with no width. As we gradually break $SU(3)$ symmetry by changing the masses, the degeneracy is

broken and the states with different strangeness and isospin split apart generating pole trajectories in the complex plane which lead us to the physical situation in the final point.

We also have evaluated the residues of the poles from where the couplings of the resonances to the different coupled channels was found. This allows us to make predictions for partial decay widths into a decuplet baryon and a pseudoscalar meson. Although there is very limited experimental information on these decay channels, this represents an extra check of consistency of the results of this model.

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